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INVESTIGATIONS IN CONTROL OF HEMIPTEROUS COTTON INSECTS IN ARIZONA BY THE USE OF INSECTICIDES

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Introduction

The problem of reducing the damage caused to cotton by hemipterous insects in Arizona has been receiving serious consideration during recent years. In 1938 a circular[2] was issued by the Bureau of Entomology and Plant Quarantine giving the progress of experimental work up to and including the season of 1937. That circular described the methods which had been followed in determining the relative economic importance of each species to the cotton crop, discussed the more economically important species, and included a description of the character of the damage inflicted to the cotton plant by the different groups of insects. It concluded with a resume of the experiments in control with insecticides, which had been conducted to that time, together with recommendations of measures which had been indicated as practical and profitable as a result of these experiments.

Since Circular E-439 was published, 2 more years of experimental control work have largely confirmed the correctness of the information given therein. The present circular is intended to supplement the earlier one by reporting the results of 2 more years of experiments, including, last season, the use of airplane dusting.

The More Important Hemipterous Insects Attacking Cotton in Arizona

Out of 53 species of hemipterous insects collected on cotton in Arizona, 8 were listed in Circular E-439 as being those most injurious to

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1/ The writers were assisted in the field by W. A. Stevenson, H. G. Johnston, L. W. Sheets, J. M. Breazeale, and H. J. Crawford.

2/ Cassidy, T. P., and Barber, T. C. Hemipterous Cotton Insects of Arizona and Their Economic Importance and Control. U. S. Dept. Agr., Bur. Ent. and Plant Quar. Circ. E-439. (Mimeographed.)

the cotton crop. These included three pentatomids, Euschistus impictiventris Stål, Chlorochroa sayi Stal, and Thyanta custator Kirk.; four mirids, Lygus hesperus Knight, Lygus pratensis oblineatus (Say), Creontiades femoralis Van D., and Psallus seriatus (Reut.); and one pyrrhocorid, Dysdercus mimulus Hussey.

A change has occurred during the past 2 years in the importance of Dysdercus mimulus. For some unknown reason this species, which was then abundant, has become so scarce, especially in the Salt River Valley, that among collections at thousands of points in 1939 only two or three specimens were found. While this insect was so scarce that it was not considered of much economic importance in 1939, it must be recognized that at any time it may reappear in damaging numbers.

The increasing importance of the mirid Creontiades femoralis should also be emphasized. This species is apparently increasing in the main Arizona cotton areas, particularly in the south side of the Salt River Valley, where for the past 2 years it has greatly outnumbered the combined populations of the two species of Lygus, which were formerly considered the most common and destructive mirids. Repeated experiments have proved C. femoralis to be more destructive to the cotton plants, insect for insect, than either of the species of Lygus. Moreover, Creontiades can maintain itself and multiply readily on the cotton plants throughout the growing season, whereas Lygus can maintain itself in the cotton fields only after the plants have become large enough to furnish heavy shade and are squaring and fruiting heavily. Even then it does not multiply rapidly on cotton, and most of the population comes from migrations from other host plants in the vicinity.

With the foregoing modifications the original list of the more injurious hemipterons in Arizona cotton fields is still accurate. No new hemipterous insects of marked economic importance to the cotton crop have been found in Arizona during the past two seasons.

Nature of Damage to Cotton by Pentatomids (Stink Bugs)

The three important species of stink bugs in Arizona cotton fields are boll feeders, and feed but little on either the foliage or squares. The damage caused by boll puncturing is greatly aggravated by lint staining, which follows as a result of pathogenic organisms that gain entrance to the bolls through the punctures. Punctured bolls are shed in large numbers, but the ones not thrown off may exhibit varying degrees of injury from a small stain in one lock of the matured boll to what is termed an "unpickable boll," which is a mummified, half-opened boll with the lint in every lock impacted, stained, short, weak, and of little or no market value. In heavily infested fields a high percentage of the bolls are unpickable and remain on the plants after the crop has been picked, and in extreme cases the yield may be reduced by more than one-half.

Nature of Damage to Cotton by Mirids (Leaf Bugs)

The damage caused to cotton by Lygus spp., Creontiades femoralis, and other mirids differs from that of the pentatomids in that it is mainly

concentrated upon the terminal buds, squares, and small bolls. The bud injuries frequently result in a deformed vegetative type of growth, due to excessive branching of adventitious buds following the destruction of the terminal buds. The square injury causes heavy shedding resulting in a reduction of the ultimate crop, although the squares shed are partially compensated for by the tendency of the cotton plant to put on extra fruit to replace early losses. Damage is also inflicted on small bolls, resulting in considerable shedding and light lint staining, but the boll damage is much less severe than in the case of the pentatomids, and the staining is not so pronounced. Although the work of the mirids is not so conspicuous as that of the pentatomids, the total amount of loss will closely approach, if not exceed, that caused by the stink bugs.

Indirect Loss from Hemipterous Insect Damage

In addition to the direct injury to the cotton, a secondary source of trouble consists of the dissatisfaction among the cotton pickers in fields which have been heavily damaged by hemipterous insects. The cause of the trouble is the sticking of the lint to the proliferations within the punctured bolls, augmented by the tendency of badly punctured bolls to open only partially, so that undue effort is required to pick the cotton from them. These punctured bolls often require several "pulls," while in a clean, unpunctured boll the lint can usually be gathered with a single motion of the hand. Since in damaged fields the amount of cotton a picker can gather is determined largely by the percentage of punctured bolls, the pay is correspondingly reduced. This aspect sometimes assumes serious proportions, the pickers migrating from camp to camp in an effort to locate "clean" cotton fields.

The effect of hemipterous insect injury upon the Arizona cotton crop was summarized in Circular B-439 as follows:

"(1) It reduces the total amount of the crop by causing abnormal cotton plants and heavy shedding of the squares and small bolls.

"(2) It reduces the grade and value of the lint on account of the staining which follows the attacks of the boll-feeding species.

"(3) In cases of heavy infestation it renders a certain percentage of the crop 'unpickable' and valueless through the almost complete destruction of many bolls.

"(4) It reduces the value of the seed for planting or milling, as many seeds are injured in early development and fail to mature. Many of the faulty seeds are also broken in ginning and become mixed with the lint.

"(5) It causes much dissatisfaction among the cotton pickers by slowing down their work and hence reducing their pay."

Extent of Damage to Cotton by Hemipterous Insects in Arizona

Accurate estimates of the losses from bud, square, and small boll injuries are more difficult to obtain, but much information has been secured on the damage inflicted by hemipterous insects upon the mature bolls. From 1934 to 1939, inlcusive, an intensive survey was made each fall of the main cotton-growing areas of Arizona. Representative cotton fields were selected in all these areas, and cotton bolls were collected from five points in each field. Many thousands of cotton bolls were thus collected each year, all of which were brought into the laboratory and examined individually, both externally and internally. A summary of the results of these annual surveys is shown in table 1.

Table 1. -- Damage to cotton bolls by hemipterous insects in Arizona cotton areas, 1934 to 1939, inclusive

Year	Short-staple cotton		Long-staple cotton	
	Number of bolls examined	Percentage of bolls punctured	Number of bolls examined	Percentage of bolls punctured
1934	18,393	23.4	--	--
1935	30,700	27.2	--	--
1936	41,500	24.8	12,500	6.13
1937	21,200	23.5	5,000	7.7
1938	43,810	31.5	30,958	14.63
1939	35,000	28.2	27,500	8.73
Total	190,603		75,958	
Average		26.3		9.29

These figures show that over a period of 6 years an average of 26.3 percent of the short-staple bolls for the State had been punctured by hemipterous insects. In long-staple cotton the damage by boll-feeding insects is materially less, but considerable evidence has been gathered to indicate that the bud and square injury is probably as great as if not greater than in the short-staple cotton.

The comparative amount of boll injury varies greatly, yet consistently, with the locality. For 6 consecutive years Yuma County, in the southwestern corner of the State, has shown the heaviest hemipterous insect injury, ranging from 40.3 percent in 1937 to 62.1 percent in 1939, with a 6-year average of 53.7 percent. Pima County has as consistently shown the least injury, ranging from 5.1 to 12.2 percent, with a 6-year average of 7.4 percent. The remaining cotton-producing counties have always fallen between these two extremes of infestation.

A number of factors are responsible for the differences in the amount of damage in different sections of the State, some of them unknown. The boll-puncturing species are general feeders and attack many fruits and seeds. They are frequently abundant in damaging numbers on other crops, such as alfalfa, sugar beets, and grain sorghums, and they are found in considerable

numbers on desert vegetation. The infestation in cotton is mainly due to their migrations from these alternate host plants. The proportion of land planted in other crops and their proximity to the cotton fields, the time they are harvested, the amount of rain and its effect on desert vegetation, and the density of weed growth and other vegetation, all influence the migrations of hemipterous insects to cotton and the time when damage occurs.

Control Experiments

After preliminary tests with various insecticides in lantern globes and cages, small field plots were dusted with hand guns and then larger plots of 2 to 5 acres were dusted with a five-row power duster. For the past 2 years particular attention has been given to sulfur and combinations of sulfur and paris green or sulfur and calcium arsenate. The increase in yields over the checks in the 53 plot experiments conducted during the period 1933 to 1939 are given by years for each locality in table 2 and are summarized in table 3.

Table 2.--Summary of all small-scale field control tests against hemipterous cotton insects (including all field-plot experiments of five acres or less in size), Arizona, 1933 to 1939, inclusive

Insecticide tested	Increase in yield of seed cotton (pounds) per acre in dusted plots over checks											
	Buckeye 1933	Buckeye 1934	Buckeye 1935	Buckeye 1936	Mesa 1937	Buckeye 1937	Yuma 1937	Buckeye 1938	Yuma 1938	Mesa 1938	Buckeye 1939	Mesa 1939
Calcium arsenate and sulfur	--	--	--	546[1]	--	684[2]	2,333[1]	791[2]	549[2]	169[2]	313[2]	81[2]
Paris green and sulfur	--	--	248[3]	274[4]	114[5]	818[5]	2,691[4]	392[3]	200[3]	375[3]	57[3]	117[3]
Sulfur	469	189	206	150	178	1,078	1,274	1,620	--	157	375	81
Paris green and calcium arsenate (1-3)	--	--	--	0	58	1,118	--	--	--	--	--	--
Lead arsenate	297	454	523	0	120	310	600	--	--	--	--	--
Calcium arsenate	384	--	--	34	43	818	--	--	--	13	--	--
Sodium fluosilicate	--	517	0	--	--	--	--	--	--	--	--	--
Pyrethrum	--	328	138	--	--	--	--	--	--	--	--	--
Derris	--	151	138	--	--	--	--	--	--	--	--	--
Derris and sulfur	--	--	151	--	--	--	--	--	--	--	--	--
Pyrethrum and sulfur	--	--	41	--	--	--	--	--	--	--	--	--
Paris green 7-1/2%, clay 92-1/2%	--	--	--	--	--	--	--	--	--	--	--	19

[1] Calcium arsenate 33-1/3%, sulfur 66-2/3%.
[2] Calcium arsenate 20%, Sulfur 80% (1-4).
[3] Paris green 7-1/2%, Sulfur 92-1% (1-12-1/3)
[4] Paris green 10%, sulfur 90% (1-9).
[5] Paris green 5%, sulfur 95% (1-19).

Table 3.-- Average gains from the use of different insecticides tested upon a field-plot basis in Arizona, 1933 to 1939, inclusive

Insecticide tested	Total number of experiments[1/]	Average gain in seed cotton, pounds per acre.
Calcium arsenate and sulfur	8	683.2
Paris green and sulfur	10	528.6
Sulfur	11	525.2
Paris green and calcium arsenate	3	392.0
Lead arsenate	7	329.1
Calcium arsenate	5	258.4
Sodium fluosilicate	2	258.5
Pyrethrum	2	233.0
Derris	2	144.5
Derris and sulfur	1	151.0
Pyrethrum and sulfur	1	41.0
Paris green 7-1/2%, clay 92-1/2%	1	19.0

[1/] In most experiments the treatments were replicated from one to several times, and the number of plots treated is therefore much greater than the number of experiments shown.

It will be noted that the first three insecticides listed have shown the largest gains year after year; these gains fluctuated greatly in different localities and years, as they were affected by local conditions and the intensity of insect populations. The calcium arsenate-sulfur mixtures in 8 experiments over a period of 4 years and in 3 localities have given an average gain of 683.2 pounds of seed cotton per acre over untreated check plots. The paris green-sulfur mixtures in 10 experiments over a period of 5 years in 3 localities have given an average gain of 528.6 pounds of seed cotton per acre. Dusting sulfur in 11 experiments over a period of 7 years and in 3 localities has given an average gain of 525.2 pounds of seed cotton per acre. In addition to giving the best insect control of all treatments tested, these three insecticides are available at a reasonable cost.

Airplane Cotton Dusting Experiments in Arizona, 1939

In the experiments reported above, the insecticides were applied with hand dust guns and ground power dusting machines. However, neither method of application if fully adapted for large-scale field dusting in Arizona. The hand machines are too small to be practical and require too much expenditure for labor. While a power dusting machine can efficiently dust some 50 or more acres of cotton in a night at an application cost of about one-half of airplane dusting, the use of power ground machines presents definite difficulties. The irrigation schedules interfere seriously with the use of a ground duster, as in some soils the machine cannot be used for several days after an irrigation on account of the muddy condition of the ground. When cotton reaches its maximum growth the latter part of the season, insect populations have usually reached a peak and dusting is most urgently needed, but the dusting machine cannot be drawn through the fields without causing material damage to the cotton plants and fruit. Then, too, in the event of a sudden insect migration to cotton, it may be necessary to apply insecticides at a much faster rate than can be done with a ground machine. For these reasons it is believed that hand and power machines will not be entirely suitable for average conditions in Arizona. Obviously a method of insecticide application is required which will not be affected by the field irrigation schedules, which will not injure the cotton plants when they attain large size, and moreover will permit the dusting of large acreages in the shortest possible time. The use of airplanes promises to meet these requirements. The desired type of dust cloud as applied with a ground power dusting machine is shown in Figure 1. It has been found that under ideal climatological conditions a satisfactory dust cloud and distribution of insecticides can be obtained with airplanes in Arizona. An airplane dusting cotton is shown in Figure 2.

During 1939 a series of large-scale airplane dusting experiments was conducted cooperatively with the J. G. Boswell Company and a number of cotton growers to obtain information on the efficiency, practicability, and expense involved in this method of insect control, and the minimum number of injurious hemipterous insects that would justify airplane dusting. The distribution of dusted cotton fields was planned to cover the major cotton-growing sections of the State, and they included fields located in areas

that were heavily and lightly infested in previous years. The fields were selected and arrangements made for the experiments before the insect abundance could be determined. Later examinations showed that in some fields the insects did not reach what are considered to be commercially damaging populations, and in no fields were the populations as heavy as in some of the previous experiments dusted with ground machines. However, as one of the aims of the airplane dusting experiment was to determine the insect populations that would justify control operations and produce a profit, it was decided to carry through the season 8 large-scale field experiments as planned, regardless of insect populations or cost. Each field consisted of 40 or 80 acres, half of which was dusted with a mixture of 7-1/2 percent paris green and 92-1/2 percent sulfur and half left as an untreated check. The gains over the checks in the 8 dusted fields in Maricopa County in 1939 are shown in table 4.

Table 4.--Summary of gains in the airplane dusting experiments, Salt River Valley, Arizona, 1939

Field No.	Location	Type of cotton	Gains in seed cotton, dusted plots over checks	
			Pounds per acre	Percent
1	Palo Verde	Short	47	3.2
2	Buckeye	Do.	34	2.5
3	Perryville	Do.	87	4.1
4	Marinette	Do.	208	9.3
5	Marinette	Pima	59	7.1
6	Chandler	Do.	242	40.4
7	Gilbert	Do.	154	12.5
8	Mesa	Short	240	15.7
Average 5 short-staple fields			123	6.9
Average 3 long-staple fields			152	20.0

It will be noted that despite the unfavorable insect conditions for the experiments. Increases in yields ranging from 2.5 percent to 40.4 percent were obtained. In the 5 short-staple fields an average gain of 123 pounds, or 6.9 percent, of seed cotton per acre was obtained by dusting, while in the 3 long-staple fields the average gain was 152 pounds, or 20 percent, of seed cotton. These figures and the seasonal insect population counts show that airplane dusting with the paris green-sulfur mixture will reduct hemipterous insect populations and their injury to cotton but that it will not be profitable under all conditions with low insect populations.

The population and yield records in the experimental fields of 1939 indicated that, while some increase in yields could be secured from dusting fields with light infestations, a population of 12 to 15 of the injurious species per 100 strokes with a standard sweep net is required to justify control by airplane, and that dusting should be discontinued when the insects are reduced below these numbers. Further work is needed before definite recommendations can be made as to the populations that will yield

profitable returns from control, the increase in yields that can be expected, and the number of dust applications that will give the most economical control.

There have been so many requests for the results of the airplane dusting experiments that the detailed records of two fields, one in short-staple and one in long-staple cotton, are given in the following pages.

Seasonal History and Yield Records of Experimental Field No. 8, Acala Short-Staple Cotton

This was an 80-acre field divided into four 20-acre strips, two of which were dusted and two undusted for securing comparative records in the treated and untreated cotton.

Dusting records:

Insecticide applied -- paris green 7 1/2%, sulfur 92 1/2%, at 7-day intervals.

Number of applications -- 7, at 15 pounds per acre-application.

Method of application -- airplane in early morning hours.

Dates of application -- July 13, 20, 26, August 2, 9, 16, 23.

Cost of dusting -- $1.17 per acre-application, including insecticide.

Total amount of insecticide applied -- 4,200 pounds

Hemipterous insect infestation records:

Twelve population counts made at weekly intervals.

First count made June 22 and final count made September 8.

Populations of injurious hemipterous insects:

	Number of injurious insects per 100 strokes	
	Dusted	Check
Seasonal average	8.21	10.25
Peak infestations	19	28
Period of commercial damage	3 weeks	4.5 weeks

Dusting reduced the infestation an average of 2.04 injurious insects per 100 net strokes over the season, and reduced the peak infestations by 9 insects per 100 strokes. It also reduced the period of severe damage by one-third.

Records of form counts:

Date	Average number of forms per plant: Dusted	Check
June 23	9.77	9.33
July 19	32.08	27.69
August 26	17.85(15.88 bolls)	13.96(13.27 bolls)

At the last count, the dusted plots exceeded the check plots on the average by 2.61 bolls per plant.

Record of boll examinations for hemipterous insect damage:

Date	Percent of bolls punctured: Dusted	Check
August 10	21.75	31.25
September 6	34.25	52.00

Yield of seed cotton in comparable areas:

The average yield per acre was 1,770 pounds in the dusted plots and 1,530 pounds in the check plots. The average gain in the dusted plots over the checks was 240 pounds, or 15.7 percent.

Rendition of lint:

On a field basis the gin records show that the dusted plots yielded 0.8 percent more lint from seed cotton than did the check plots.

Classing and grading records:

	Dusted		Check	
	No. of bales	Percent	No. of bales	Percent
Total yield	47	--	39	--
Grade				
Strict Middling	23	48.9	8	20.5
Middling	24	51.1	31	79.5
Color				
White	44	93.6	36	92.3
Spotted (last picking)	3	6.4	3	7.7
Staple				
7/8"	2	4.3	2	5.1
15/16"	3	6.4	6	15.4
1"	14	29.8	16	41.0
1-1/32"	24	51.0	10	25.7
1-1/16"	4	8.5	5	12.8

It is seen that a higher percentage of lint was produced and a better grade and staple was obtained in the dusted cotton.

Value of Acala seed cotton

With a gin lint turn-out of 36.5 percent, 9.5 cents per pound for the lint and $24 per ton for the seed, 100 pounds of seed cotton would bring the following returns:

36.5 pounds of lint at $0.095	$3.47
63.5 pounds of seed at $0.012	0.76
Total	$4.23

From the extra yield attributable to dusting, however, the following costs per hundred pounds of seed cotton would have to be deducted:

Picking and hauling	$0.95
Ginning	0.30
Bagging and ties	0.09
Total	$1.34

The net value of 100 pounds of Acala seed cotton would therefore be $4.23 minus $1.34, or $2.89 per hundred.

Computing profit from the above figures, and not considering the increased value of the dusted cotton due to an increase in lint turn-out and a better grade and staple, the value of 240 pounds of seed cotton gained per acre as a result of dusting is $6.94. The cost of seven applications of dust at $1.17 per acre-application is $8.19, which shows a net loss of $1.25 per acre. However, at least three applications of dust were made in the experiments before the insect population reached damaging numbers, and it is believed that four applications would have given the same yields and a profit of $2.26 per acre.

. Seasonal History and Yield Records of Experimental Field No. 6, Long-Staple Cotton

This was a 40-acre field of Pima cotton divided into four 10-acre strips, two of which were dusted and two untreated. The field was divided into 1-acre plots for securing yield records in the dusted and undusted cotton.

Dusting records:

Insecticide applied -- paris green 7 1/2%, sulfur 92 1/2% at 7-day intervals.

Number of applications -- 7, at 15 pounds per acre-application.

Method of application -- airplane, in early morning hours.

Dates of application -- July 13, 20, 26 -- Aug. 2, 9, 16, 23.

Cost of dusting -- $1.17 per acre-application, including insecticide

Total amount of insecticide applied -- 2,100 pounds.

Hemipterous insect infestation records:

Twelve population counts made at weekly intervals.

First count made June 22 and final count made September 8.

Number of injurious insects per 100 strokes

	Dusted	Check
Seasonal Average	14.25	20.10
Peak infestations	27	37
Period of severe damage	6 weeks	7 weeks

Dusting reduced infestation an average of 5.85 injurious insects per 100 net strokes over the season, and reduced the peak infestations by 10 insects per 100 strokes. It also reduced the period and intensity of severe damage.

Records of form counts:

Average number of forms per plant

Date	Dusted	Check
June 24	3.83	3.96
July 19	14.01	12.75
August 24	42.55 (13.64 bolls)	36.78 (11.53 bolls)

At the final count, the dusted plots exceeded the check plots on the average by 2.11 bolls per plant, although the long-staple cotton had not yet reached the peak of the fruiting stage.

Record of boll examinations for hemipterous insect damage:

Percent of bolls punctured

Date	Dusted	Check
August 10	8.75	19.50
September 7	14.00	26.75

The amount of boll puncturing was reduced practically one-half throughout the main fruiting season in the dusted plots as compared with check plots.

Yield of seed cotton in comparable areas:

The average yield per acre was 841 pounds in the dusted plots and 599 pounds in the check plots. The average gain in the dusted plots over the checks was 242 pounds, or 40.4 percent.

Rendition of lint (gin turn-out):

On a field basis the gin records show that the dusted plots yielded 0.7 percent more lint than did the check plots.

Classing and grading records:

	Dusted		Check	
	No. of bales	Percent	No. of bales	Percent
Total yield (first picking)	8	--	7	--
Grade				
No. 1	5	62.5	0	--
No. 2	3	37.5	7	100.0
Staple				
1-1/2"	2	25.0	4	57.1
1-9/16"	6	75.0	3	42.9

It is seen that a higher percentage of lint was produced and a better grade and staple was obtained in the dusted cotton.

Value of Pima seed cotton:

With a gin lint turn-out of 25 percent, 20 cents per pound for the lint and $24 per ton for the seed, 100 pounds of Pima seed cotton would give the following returns:

25 pounds of lint at $0.20	$5.00
75 pounds of seed at $0.012	.90
Total	$5.90

From the extra yield attributable to dusting, however, the following costs per 100 pounds of seed cotton would have to be deducted:

Picking and hauling	$1.85
Ginning	.60
Bagging and ties	0.06
Total	$2.51

The net value of 100 pounds of Pima seed cotton would therefore be $5.90 minus $2.51, or $3.39 per hundred.

Computing the value of the gains and costs of dusting from the above figures, but without taking into consideration the increase in value of the dusted cotton due to an increased lint turn-out and a better grade and staple, the value of 242 pounds of seed cotton gained per acre as a result of dusting is $8.20. The cost of seven applications of dust at $1.17 per acre-application is $8.19, which shows a net gain of 1 cent per acre. However, it will be noted that insect populations in the dusted areas of this field were present in damaging numbers for a period of 6 weeks, which should have required only 6 applications of dust instead of 7 and would have left a profit of $1.18 per acre. The yields in this field were low, the undusted check producing only 600 pounds of seed cotton per acre. Ordinarily Pima cotton produces from three-fourths to one bale per acre on suitable land for Pima in Arizona, and a gain of 40 percent in cotton from such areas will justify several applications of dust and still give a profit.

Definite information on the increased value of the lint resulting from the improvement in grade and staple in the airplane-dusted fields is not available at this time. A study of the classing and grading records shows, however, that this should be a considerable item. In fact, one large company that has been dusting with airplanes for several years considers that the increased value of the cotton alone will pay for all costs of dusting even though there is no increase in yield.

Recommendations for Hemipterous Insect Control in Cotton

Experiments conducted over a period of 7 years have shown that hemipterous insect damage to cotton can be profitably reduced by the use of several insecticides applied by hand and ground machinery. The increases in yields from 1 year's experiments with airplane dusting were not enough to pay the costs of dusting. This is attributed to the comparatively low insect populations in the experimental fields and the fact that more applications of dust were made than were needed. It is believed that further experiments will show that dusting with airplanes has certain advantages over ground machinery and can be profitably used for the control of hemipterous insects on cotton. A number of factors influence the results that may be expected from dusting in various cotton-growing areas of the State, such as the soil fertility, surrounding crops, wild host plants, size and stage of cotton growth, the relative proportion of the different species of injurious insects present, and the intensity of the insect populations. In planning control for hemipterous insects the general recommendations that

follow are suggested.

Hemipterous Insect Populations in Cotton

Insect populations should be determined in all cotton fields before dusting operations are begun. The methods used for making population counts are sweeping with a standard sweep net 15 to 16 inches in diameter, and plant examinations. In fields that are to be dusted, sweepings should be started the latter part of June or when the cotton plants begin to set squares and bolls. The sweeping should be made at regular weekly intervals by making 300 or 400 net strokes in representative areas of the field. The sweeps should be made across the rows by hitting the tops of about every other plant with the net. When 100 net strokes have been made, the insects and debris should be shaken down to the bottom of the net and sprinkled with while gasoline to kill or stupify the insects so they can be counted and recorded. When the sweepings have been completed in a field, the total number of injurious hemipterous insects collected should be divided by the number of 100-stroke units, and if it is found that 12 to 15 specimens of injurious species are present per 100 net strokes, dusting should be started and continued at 7-day intervals until the numbers of injurious insects have been reduced below this point. Although very few leaf bugs or mirids may be present, it has been found that stink bugs often migrate into cotton fields in great numbers, especially when sugar beets or alfalfa grown for seed is harvested. Since stink bugs are heavy-bodied insects and feed principally upon the bolls located low on the plants, a smaller percentage of those present are collected by the sweeping method than of the lighter bodied mirids. In fields where heavy stink bug migrations occur, the plant examination method is used for determining the populations by examining 300 to 400 plants in representative areas of the field. When 6 to 8 are found per 100 plants, poisoning should be started and continued as described above until the stink bugs have been reduced below this point.

Insecticides for Hemipterous Insect Control

The insecticide to be used will depend upon the insects present. If the insects are almost entirely mirids.(*Lygus* spp. and *Creontiades* sp.), dusting sulfur may give the most economical control. If pentatomids are present in any appreciable numbers, as they usually are in all cotton areas of Arizona, an arsenical-sulfur mixture will give better results. Repeated experiments have shown that sulfur alone does not give satisfactory control of stink bugs, while mixtures of paris green and sulfur and of calcium arsenate and sulfur give economical control in fields where the populations are great enough to justify the expense. The arsenical mixtures are also of value in controlling the cotton leaf perforator (*Bucculatrix thurberiella* Busck), the bollworm (Heliothis armigera (Hbn.)), and the cotton leaf worm (*Alabama argillacea* (Hbn.)). The perforator and bollworm are nearly always present, and the leaf worm sometimes is present in Arizona cotton when dusting is needed for hemipterous insects and it sometimes causes considerable damage. Some of the gains that have been secured from dusting are probably partly due to the reduction in damage caused by these insects.

The problem of the most economical insecticide to use is further complicated by costs. At present prices dusting sulfur (98 percent 325-mesh, at least 95 percent pure) can be bought in quantities at around 4 cents a pound, the 20 percent calcium arsenate and 80 percent sulfur mixture at 5 to 5-1/2 cents, and the 7-1/2 percent paris green and 92-1/2 percent sulfur mixture at 5-1/2 to 6 cents a pound. The results of several years ofexperiments show that for average conditions the calcium arsenate-sulfur mixture or the paris green-sulfur mixture will give the most profitable results, the choice depending largely on the preference of the individual grower and the availability of the materials. In both cases the materials should be thoroughly mixed by machinery for best results. These recommendations for insecticides are not to be considered as final, as they may be changed from time to time as investigations progress.

Applications and Cost of Treatment

When insect populations reach commercially damaging numbers the insecticide selected for use should be applied at the rate of 15 pounds per acre per application at 7-day intervals until the injurious species have been reduced below 12 to 15 insects per 100 sweeps, or, in the case of stink bugs, below 6 to 8 per 100 plants by the plant-examination method. In applying the insecticides with airplanes or any type of dusting machinery, a thorough coverage and uniform distribution of the dust are necessary. This can be best secured by dusting at night or early in the morning when atmospheric conditions are more favorable. Where large acreages are to be dusted, commercial airplane dusting companies will apply the insecticides for 40 to 50 cents per acre per application. Where power dusters can be used advantageously, growers could probably apply their insecticides cheaper than this. The expense of dusting will range from about $1.00 to $1.40 per acre per application. The number of insecticide applications required may vary from 2 to 9 per season, depending upon the abundance of the insects, but usually 5 or 6 dustings are sufficient.

Poisoning Bees

Considerable apprehension has arisen over the danger of poisoning bees by arsenical dusts used for the control of cotton insects, especially when airplanes are used for dusting. A few cases of damage to apiaries have been reported, but these have been due largely to the drifting of dust to adjacent fields around the edges of the cotton. The danger can be greatly reduced by cutting off the dust in time when nearing the end of the field and closing the hopper tightly while zooming and turning over adjacent property. The State entomologist at Phoenix should be notified several days in advance when dusting is to be done in a locality. He has arranged to notify all beekeepers in the vicinity so they can move their bees to other areas. Cooperation with beekeepers by cotton growers and airplane pilots in taking precautions to prevent drifting of dust and giving advance information as to when dusting will begin will reduce danger of damage to bees and the objections of beekeepers to dusting.

Summary

The more important injurious hemipterous cotton insects in Arizona include three species of Pentatomidae, four species of Miridae, and one species of Pyrrhocoridae. Several additional species inflict lesser injuries.

The damage consists of (1) injury to the small buds, causing malformation in the growth of the plants; (2) injury to squares and small bolls, causing them to shed; and (3) puncturing of the bolls, resulting in shedding or in deformed and abnormal bolls. The boll injuries are followed by lint staining, which lowers the quality and value of the crop; and the lint from punctured bolls is more difficult to pick, causing dissatisfaction among the cotton pickers.

In addition to the damage to terminal buds and squares, annual surveys of the cotton areas in the State have shown that on the average one boll in every four is punctured by hemipterous insects. The heaviest injury invariably occurs in Yuma County, where an average of one-half of the cotton bolls are damaged, while the lightest damage occurs in Pima County, where only about 1 boll in 13 is damaged.

In dusting for the control of hemipterous insects on cotton, the following general rules should be observed:

(1) Commence dusting when 12 to 15 injurious hemipterous insects can be collected per 100 sweep-net strokes, or when 6 to 8 stink bugs are found by examining 100 plants.

(2) Dust with calcium arsenate and sulfur (1-4), paris green and sulfur (1-12), or straight dusting sulfur. The present information indicates that dusting sulfur will give the most economical control of the mirids, but for general use where stink bugs and other insects are also present the arsenical-sulfur mixtures are better.

(3) All insecticide applications should be made at the rate of 15 pounds per acre per application at night or early in the morning when atmospheric conditions are most favorable for dusting.

(4) Insecticide applications should be made at 7-day intervals until insect populations have been reduced below damaging numbers.

(5) The number of insecticide applications required may vary from 2 to 9, depending on the abundance of insects.

(6) Under average conditions the cost of dusting will range from about $1.00 to $1.40 per acre per application.

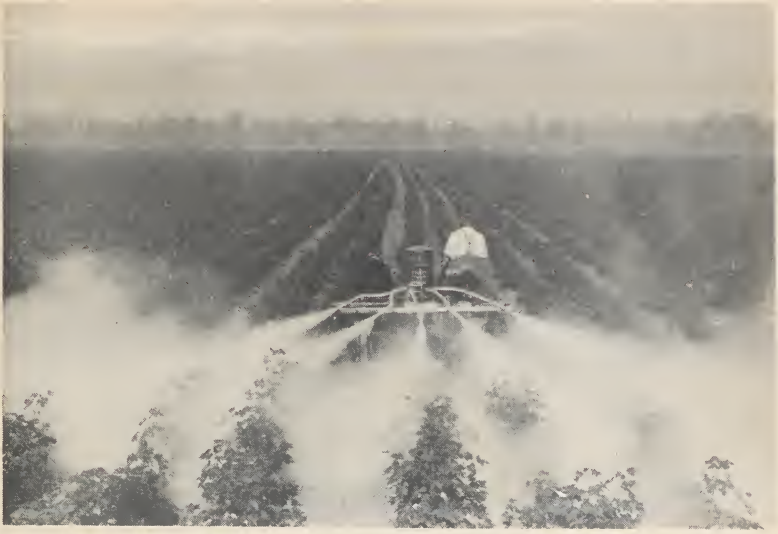

Figure 1.--Power ground machine in operation, showing satisfactory dust cloud.

Figure 2.--Dusting airplane in operation. The dust cloud should settle among cotton plants in the same manner as shown in figure 1.